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USAFOEHL REPORT

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FOR HEALTH & ENVIRONMENT

BASELINE INDUSTRIAL HYGIENE SURVEY at the FAIRCHILD AFB WA COAL FIRED HEATING PLANT

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October 1988

Final Report

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Human Systems Division (AFSC)
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This report documents the occupational health conditions and exposure at the Fairchild AFB WA coal fired heating plant. The plant contained many traditional industrial hygiene concerns that were expected and adequately addressed by the base industrial program: noise, asbestos, welding, lighting, etc. Our survey concentrated on the industrial hygiene problems unique to burning coal. Delivering, transporting, pulverizing and burning of coal were not problem areas. Coal handling in the coal yard could overexpose the front-end loader operator to coal dust. Ash handling throughout the plant caused problems due to the extremely fine ash that is the end product of burned pulverized coal. Engineering controls and respiratory protection were recommended.

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CONTENTS

Illustrations

I. INTRODUCTION

A. Background: USAFOEHL was requested by HQ SAC/SGPB to assess the industrial hygiene problems unique to the coal-fired heating plants at Fairchild, F.E. Warren and Malmstrom AFBs. Our survey results were to be used to determine if recent emphasis on coal combustion at SAC bases contributes to unhealthy work environments. A presurvey of the Fairchild AFB plant was performed in Jan 87 and the sampling survey was done the following year during the week of 21 to 24 Jan 1988. The Fairchild AFB plant was the last to be surveyed due to equipment problems which forced coal burning to be suspended until the fall of 1987.

B. Purpose: Our intention was to document the occupational health conditions and exposures associated with coal combustion; and to recommend controls, procedures and personal protective equipment that would promote healthful work environments within the coal fired heating plant.

C. Problem: The main heating plant at Fairchild AFB was fired with natural gas throughout the 1986/87 heating season and during the start of the 1987/88 heating season. Prior to December 1987, coal firing was suspended due to a faulty waste ash transport system. Without properly working waste ash handling equipment, ash disposal was an extremely dusty operation that was unacceptable for health, safety and maintenance reasons. An improved design of a waste ash auger-slurry maker was installed in 1987 to abate the waste ash transfer problems. The full-time coal burning operation was brought on-line in December 1987.

D. Scope: Our survey objective was to monitor the plant workers' exposure to the dusts resulting from coal combustion. We did this by performing personal air sampling for coal and ash dust around-the-clock on all shifts during the length of our survey, and by taking area air samples and bulk samples to augment our personal exposure data. Routine heating season operations were addressed. We did not have the opportunity to address emergency procedures, or any off-season maintenance operations which would normally take place during the summer.

E. Survey Personnel:

Capt Frank B. Liebhaber Jr. CIH
Lt Clinton Stuart

II. FINDINGS

A. Diligent management and constant work attention kept the plant relatively clean and well maintained. This was commendable considering the plant's advanced age of over 40 years and the constant house cleaning problems associateo with burning powdered coal. The plant had four boilers which were capable of burning oil or natural gas, but three of them had been converted to burn pulverized coal.

B. The plant contained many traditional industrial hygiene concerns that were adequately addressed by the base industrial hygiene program: noise, asbestos, welding, lighting, etc. These were not addressed by our survey.

C. Our survey concentrated on the industrial hygiene problems unique to burning coal. Coal delivering, conveying, pulverizing and burning did not seem to be problem areas. However, the front-end loader operator working in the coal storage yard has the potential to be overexposed to coal dust. The coal delivery, storage and use process begins with dump trucks delivering and unloading the coal into storage piles in the coal yard. The coal is then moved to the conveyor chute using a front-end loader. The conveyor transports the coal to in-plant storage silos, which feed through coal crushers to the boilers. The process of coal delivering, unloading, storing and front-end loader handling takes an average of about six hours. Though routinely done about once every three days, the frequency of this process is dependent on the coal usage. Other than working in the coal yard, workers are not routinely exposed to coal dust unless they are doing maintenance on the coal conveyors and crushers.

D. The areas of significant industrial hygiene concern were those which involved ash handling. Ash resulting from burning pulverized coal is extremely fine and difficult to handle. There are basically four types of ash: bottom ash, fly ash, flue gas desulferization system (SDS) ash, and waste ash.

1. Bottom ash is coal ash that falls to the bottom of the boiler. Bottom ash must be manually disgorged from the bottom of the boiler into the pneumatic ash transport system. At regular intervals during each shift, a boiler operator must sweep the bottom ash through a boiler trap door into the boiler's ash collection hopper where the ash is then sucked away. A portion of the bottom ash consists of "clunkers." These are large chunks of fused ash, mostly metals and minerals such as silica. Clunkers must be removed from the ash stream before the ash enters the pneumatic ash transport system. Otherwise, the clunkers would clog up the pneumatic plumbing. A course screen in the boiler's ash collection hopper separates out the clunkers, which are then removed by the boiler operator after all the other ash has been whisked away.

2. Fly ash is the very light ash that remains in the flue gas stream until it is removed by the baghouse filtration system. Most of the fly ash collected by the baghouse is transported to the waste ash holding silo via mechanical chain conveyors and pneumatic plumbing.

3. SDS ash is made with a portion of fly ash that is diverted to the flue gas desulferization system (SDS). Here the fly ash is mixed with quick lime (calcium oxide) and water to form a slurry called "milklime." Milklime is sprayed into a reaction cyclone, counter-current to the flue gas stream. The sulfur dioxide in the flue gas reacts with the milklime to produce calcium sulfate and sulfite. These reaction products dry, then fall to the bottom of the reaction cyclone along with excess fly ash and unreacted lime. These reaction cyclone bottom products, which we call "SDS ash," are routed to the waste ash silo by chain conveyor and pneumatic plumbing. Some of the SDS ash is too fine to be removed by the SDS reaction cyclone. This ash, which follows the flue gas out of the SDS cyclone, is removed in the baghouse prior to the flue gas being released to the atmosphere.

4. Waste ash is a composite consisting of all the other ashes and any other dust that gets into the disposal system, all of which are stored for disposal in the waste ash silo. The bulk of the waste ash was very fine and had a consistency similar to flour.

E. A new "dustless" waste ash transfer system was used for moving ash being held in the waste ash silo into a dump truck. We were told by workers prior to the survey that most of the time the system worked well, but occasionally it had mixing problems which in theory could be immediately fixed by an experienced operator. This ash transfer system was designed to perform dustless during dumping by mixing water with the waste ash to agglomerate a slush which has a consistency similar to Portland cement before curing. However, the auger-slurry maker was not mixing properly during half of the ash dumping operations done during our survey. On these occasions, the ash would exit the system either too watery, like a thin soup, or too dry and clumpy. These conditions would make the dumping operation extremely dusty and would force the operators to wear respirators, usually the disposable types.

F. The baghouse ash transfer system was a combination of chain conveyors and pneumatic plumbing. The pneumatic portion of the system worked without problems, but the conveyor portion had numerous shutdowns due to clogged lines and chain breakage. Often when the chain conveyor experienced problems, the ash being held in the baghouse hopper would build up and plug the hopper's exit chute. This blockage would have to be manually opened by a SDS operator who would access and rod out the plug in the hopper's exit chute through a 6-inch diameter clean-out port. The problem here was when the clean-out port's cap was unscrewed, the static pressure of the ash in the baghouse hopper would violently force the ash out the clean-out port. This ensuing ash "gusher," in addition to creating an immense dust problem, would at times endanger the operator by knocking him off his ladder, or spraying his eyes with ash. In these situations the SDS operator would wear a face shield and respirator. The respirators used were either disposable dust masks, or Bullard "Free Air" System 999 airline hoods connected to individual carbon-vane air pumps.

G. There were three potentially hazardous operations which are normally done during the summer that we did not have the opportunity to witness or monitor: (1) We were told that cleaning the boilers is a very dusty operation. (2) Filter maintenance on the pneumatic ash transport system was not observed, nor sampled. (3) The baghouse bag changing which should take place every four years has yet to be done.

III. EXPOSURE MONITORING METHODS

A. Background: Respirable dust refers to particulate mass that can penetrate a separator whose size collection efficiency is described by a cumulative log-normal function with a median aerodynamic diameter of 3.5 ± 0.3 micrometers (μm) and with a geometric standard deviation of 1.5 ± 0.1 μm. Total dust refers to all particles that cannot penetrate a separator whose size collection efficiency is determined by a 0.8 μm pore size matched weight filter.

B. Air Sampling Methods: Each employee was monitored for respirable coal and ash dust during their full shift, usually an 8-hour sample. Some short-term samples were taken during special short duration operations. In each case, the sampling train used consisted of a DuPont Alpha I personal sampling pump connected to a SKC stainless steel cyclone in series with a closed-face 37 mm filter cassette containing 0.8 μm pore matched weight filters. While sampling, the cassette was positioned in the employee's breathing zone and the pump, operating at 1.9 liters per minute (lpm), was positioned in the employee's back pocket, or clipped to his belt. The same sampling train was used for the total dust samples, except the cyclones were omitted and the cassettes were open-faced. All the sampling trains were calibrated before and after each air sample.

IV. EXPOSURE STANDARDS

A. The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV®) booklet, 1987-1988, defines TLV-Time Weighted Average (TLV-TWA®) as the TWA concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. Table 1 contains the TLV-TWA standards referenced in this report.

Table 1
STANDARDS

Substance	TLV-TWA Concentrations (mg/m^3)
coal dust, <5% quartz, respirable dust	2
coal dust, >5% quartz, respirable dust	0.1
ash <5% quartz (nuisance dust), total dust	10
ash >5% quartz, respirable dust	0.1
nickel	1.0
barium	0.5
chromium metal	0.5
manganese	5
zinc	10
copper	1
lead	0.15
lead (OSHA PEL)	0.05
arsenic	0.2

V. RESULTS AND DISCUSSION

A. Bulk Samples:

1. Silica: Coal and ash bulk samples were taken and analyzed for silica (quartz) content by x-ray diffraction because air sample concentrations are evaluated based on their silica content. Bulk sample results showed the silica content to be 6.9 ± 1.9% in the coal, 3.6 ± 0.5% in the baghouse ash and 16.9 ± 1.2% in the waste ash. These values are applicable to air samples taken in areas where only the single contaminate was present, i.e., coal sample for the coal yard worker. For full shift TWA air samples taken during general duties in different areas of the plant when the employee's movement would mix ash and coal dust exposures, it would be more appropriate to compare a mixed dust silica percentage to the air sample results, or do silica analysis on each of these "composite" dust air samples. The composite dust silica percentage of the samples taken during our survey was calculated to be 9.1 ± 6.4%. One final note is that silica content changes with each coal batch. Therefore, every time air sampling is done, the percentage of silica in both the bulk and air samples would need to be determined.

2. Metals: The results of bulk coal and ash samples analyzed for metals are shown in Table 2. Since the raw sample results were reported as micrograms per gram (μg/g) of bulk sample, we converted this data to hypothetical air concentrations for comparison to existing health standards. Our theoretical conversion assumed that the air sample results had the same ratio of mass to metals as the bulk samples. Based on the average TWA of a baghouse worker exposed to 0.31 mg/m^3 of ash dust, our calculations showed that there should be no significant exposures to metals. Other plant workers with lower average dust TWAs were calculated to have had even less exposure to metals.

Table 2
METALS IN COAL AND ASH SAMPLES

Metal	Mass Conc. (μg/g)	TWA Concentrations Typical for a full shift (μg/m^3)
Chromium	<100	<0.03
Iron	~10000	3.32
Manganese	<100	<0.03
Nickel	~200	0.08
Zinc	<100	<0.03
Copper	<100	<0.03
Lead	<100	<0.11*
Arsenic	<10	<0.003
Barium	~1000	0.341

* worst case exposure based on 1.1 mg/m^3 dust 8 hour TWA
~ approximate values based on three types of coal/ash samples

3. **Radium**: We also analyzed the bulk samples for radium 224 and 226. Based on our radium sample results, we calculated daily occupational exposures of approximately 0.005 picocuries per cubic meter of air (pCi/m^3) additional to the ambient activity of about 1000 pCi/m^3 for radon. Therefore, the occupational activity load contributed a very minor and insignificant portion to the background level.

B. Air Sampling: The results from the around-the-clock sampling done during our survey are listed in Tables 3-6. The majority of these samples were taken during the worker's full 8-hour shift, but some of these samples have slightly less than eight hours of air drawn through them because of the unavoidable time consumed by sampling train set-up and retrieval. Unless otherwise noted, we considered the listed concentrations as eight hour time weighted averages (8-hour TWA). All the samples were breathing zone respirable dust samples unless noted as a blank sample, a total dust sample, or an area sample.

Table 3
COAL AND ASH DUST CONCENTRATIONS

Sample No. (8800xx)	Operation	Shift	TWA Conc. (mg/m^3)
01	general maintenance	D	0.23
02	boiler operator	D	0.48
03	boiler operator	D	0.54
04	baghouse SDS operator	D	0.91
05	baghouse SDS operator	D	0.61
08	shift foreman	S	<0.001
09	boiler operator	S	<0.001
10	baghouse operator	S	0.09
11	boiler operator	S	0.17
12	baghouse operator	N	0.05
13	shift foreman	N	0.12
14	baghouse operator	N	0.06
15	baghouse operator	S	0.25
16	boiler operator	D	<0.001
17	shift foreman	D	0.07
18	boiler operator	D	0.10
19	coal yard truck driver	D	<0.001
20	coal yard front-end loader	D	0.44
21	1/2 day coal yard, 1/2 day plant	D	0.29
23	general maint/boiler operator	S	1.16
24	boiler operator	S	0.10
25	boiler operator/ash pulling	S	0.09

Table 3 (Cont'd)

Sample No. (8800xx)	Operation	Shift	TWA Conc. (mg/m³)
26	shift foreman	S	<0.001
27	baghouse SDS operator	S	0.03
28	general maint/boiler operator	N	0.16
29	boiler operator	N	0.17
30	baghouse SDS operator	N	0.54
32	baghouse operator	D	0.11
33	boiler operator	D	<0.001
34	baghouse operator	D	0.57
35	blank		<0.001
36	blank		<0.001
39	boiler operator	S	0.12
40	boiler operator	S	0.11
43	baghouse operator	S	1.10
44	baghouse operator	S	0.07
46	boiler operator	N	<0.001
47	baghouse operator	N	<0.001
48	shift foreman	N	<0.001

D = day, S = swing, N = night shifts

1. For the results listed in Table 3, the average ($n = 37$) respirable dust concentration was 0.24 ± 0.30 mg/m^3. The worst case exposure was computed at the 95% confidence level to be 1.10 ± 0.18 mg/m^3. The coefficient of variation for gravimetric analysis is 0.09 mg. These respirable dust samples may be doubled to approximate a total dust TWA measurement. This estimation technique may be useful when applying a respirable dust TWA concentration to a total dust TLV. Because many times workers are assigned different duties during their employment at the plant (i.e., a boiler operator may pull SDS duties for a week then work the coal yard for a few days before again doing boiler maintenance) a composite average TWA is applicable to most of the plant workers. The exception being the plant managers above the foreman position.

2. To evaluate the measured dust concentrations, we had to assign the air sample results to either the above, or below 5% silica TLV. The results for the bulk samples indicated the coal dust, waste ash and composite dust exceeded 5% silica. To verify this, we had the survey's most significant dust samples analyzed for both total weight and silica. Of these dually analyzed samples, the coal and baghouse ash air sample results, shown in Table 4, agreed with the bulk sample indications, but the waste and composite ash air samples differed with the silica content measured in the bulk samples.

Table 4
CONCENTRATIONS OF DUSTS WITH SILICA CONTENT

Sample No.	Operation	Type Dust	Concentrations (mg/m^3) Whole dust	Silica Only
06	ash dumping operator**	waste ash	95.03	4.5
41	ash dumping operator**	waste ash	30.12	1.3
42	ash dumping room	waste ash	232.37	12.3
			TWAs	
20	coal yard worker	coal	0.44	0.03***
31	general maintenance**	composite	3.93	<0.1
34	baghouse SDS operator	baghouse ash	0.57	0.02***
39	boiler operator	composite	0.12	0.01***
43	baghouse SDS operator	baghouse ash	1.10	0.04***

** respirator worn
*** modified concentration

The three asterisked (***) concentrations shown in Table 4 were <0.1 mg/m^3 results modified by calculating the silica concentration based on the bulk sample silica percentage. This was the only way to estimate the airborne silica concentration since the analytical methods (x-ray diffraction) sensitivity was only as low as the >5% silica TLV. Unlike the silica percent in the bulk samples, the air samples of waste ash were analyzed to be 4.8 ± 0.5% silica. Furthermore, the theoretically calculated composite dust silica content of 9.1% did not agree with the composite dust sample 31 which was analyzed to contain no more than 2.5% silica. It's conceivable that the silica fraction was the heavier portion of the waste ash and composite dust, and was not in the same proportion of the airborne dust as it was in the bulk ash. For this report the <5% TLV will be used for the baghouse ash and the composit dust exposures and the >5% TLV used for coal dust and waste ash exposures. Future studies will need to determine which TLV to use based on the silica content present in the ash and coal at the time of the study.

3. Due to the variation of duties assigned to the workers of each shift, we attempted to show what the average dust exposures were by job category. Table 5 lists the average TWA exposures for these categories.

Table 5
AVERAGE DUST CONCENTRATION BY OPERATION

Worker/Operation	8-hr TWA Conc. (mg/m^3)	Type of Dust
boiler operators (n=16)	0.22 ± 0.29	mixed coal/ash
SDS operators (n=13)	0.36 ± 0.38	SDS/fly ash
shift foremen (n=5)	0.04 ± 0.05	mixed coal/ash

n = number of samples used to calculate mean value

a. The boiler operator's average exposure was approximately 5% of the <5% silica dust TLV, with a worst case exposure about 23% of the same TLV. The TWAs used in these comparisons did not include the boiler operator (sample 31) who was assigned waste ash dumping during the time the waste ash slurry maker was malfunctioning. These TWAs did include the exposures that occurred during ash dumpings which proceeded smoothly.

b. The SDS operator's average exposure was approximately 7% of the <5% silica dust TLV, with the worse case exposure about 22% of the same TLV. The TWAs used in these comparisons exclude those baghouse workers who wore respirators while clearing a plugged ash line, or hopper.

c. The foremen have no significant exposures. Their supervisory duties and system monitoring preclude their involvement in the more dusty operations.

4. To further delineate the exposure which corresponds to various jobs, we did definitive sampling during certain operations. Table 6 shows the results of those samples.

a. Waste ash dumping can be a hazardous operation. The dust levels generated during this job could exceed the TLV. Fortunately this operation is short, 10 to 15 minutes average. During our observation the operators were wearing some type of respiratory protection and they were able to step out of the waste ash transfer room to seek relief from the dust. The operator who was monitored by sample 31 exceeded the action level (5 mg/m^3 total dust) of <5% silica dust if his TWA concentration was to be doubled to approximate a total dust TWA; however, his true exposure, calculated to be 0.4 mg/m^3, was the measured TWA reduced by a factor of 10 to reflect his use of respiratory protection during the ash dumping operation. The operators who were monitored by samples 6 and 41 most likely exceeded the >5% silica TLV for waste ash, even though their exposures were short and they wore disposable respirators.

b. Bottom ash removal from below the boilers did not contribute significantly to the overall TWA dust exposure experienced by the boiler operators. The negative suction created by the pneumatic ash transfer system effectively controlled any fugitive dust releases during the operation.

TABLE 6
DUST CONCENTRATIONS DURING VARIOUS OPERATIONS

Sample No.	Worker/Operation	Time	Conc. mg/m^3)
06	waste ash transfer operator,** 3 operations	37 min	95.03 TD
07	bottom ash pulling, 3 boilers emptied twice	58 min	<0.001
19	coal yard truck operator	6 hr	<0.001
20	coal yard front-end loader operator	6 hr	0.44
22	SDS Bldg near slaker, area sample	4 hr	0.70
31	general maint. with duties as waste ash transfer operator**	full shift	3.93
41	waste ash transfer operator,** one operation	10 min	30.12
42	waste ash transfer room, one operation, area sample	16 min	232.37 TD

** respirator worn
TD total dust sample

c. Coal delivery to the coal yard poised no significant coal inhalation hazard to the truck driver. However, handling coal within the yard could be hazardous. The front-end loader operator was exposed to a respirable 8-hour TWA coal dust concentration of 0.33 mg/m^3. This exposure is three times the >5% silica in coal TLV.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Coal Dust: The occupational exposures associated with coal dust were minimal and well controlled for all the workers except the coal yard front-end loader operator. Even though the airborne concentration of coal dust in the coal yard was relatively low, the coal contained >5% silica and the extremely low TLV (0.1 mg/m^3) applied. This hazardous situation, if confirmed, must be abated. Resampling must be done during the upcoming heating season's initial coal deliveries. If the results of that monitoring show the coal to be >5% silica and the exposures again exceed the TLV, hazard abatement measures must be enacted. Actions to consider are:

1. Order coal that contains <5% silica.

2 Wet the coal piles with amended water before they are manipulated by the front-end loader operator.

3. Enclose the cab of the front-end loader with a filtered and climate controlled booth.

4. Install a supplied air breathing system complete with bottled air and continuous flow respirator, or fit the operator with a powered air purifying respirator.

While confirmation sampling is being done and until definitive control measures are in place, the front-end loader operator must wear respiratory protection while the coal is being worked. Any type of properly fitted respirator which provides at least a protection factor of 10 can be used.

RECOMMENDATION: The plant management should ensure the front-end loader wears a respirator during the upcoming coal yard work. Based on the resample results, the base BEE should recommend appropriate actions.

RECOMMENDATION: The plant management should ensure the front-end loader wears a respirator during the upcoming coal yard work. Based on the resample results, the base BEE should recommend appropriate actions.

B. Ash: The occupational exposures associated with the ashes generated by burning coal have the potential to produce hazardous working conditions whenever the existing controls malfunctioned, or required maintenance. The health hazards associated with ash may be more severe than those posed by coal because:

1. Ash is abrasive and can be a severe mucous membrane irritant. Eye protection should always be required for workers handling ash.

2. Ash operations are usually more dusty because they are done manually and ash is a finer material which is less easy to control.

3. Ash had a silica content that was borderline 5% which created uncertainty as to which TLV should be applied. Even though our hazard evaluation used the <5% TLV for baghouse ash and >5% for waste ash and boiler ash, future surveys may find the ash silica content changed. When in doubt, the more stringent TLV should be used.

Respiratory protection for workers handling loose ash should be required. Air purifying respirators do not usually work well in dusty environments because they plug up. Supplied air respirators are the best choice and the Bullard Systems, such as the ones on hand, are sufficient to protect the worker.

RECOMMENDATION: The plant management should require all workers when dealing with potentially large releases of ash, i.e., unplugging the baghouse hopper, changing baghouse bags, operating the waste ash "dustless" system, cleaning out boilers, etc., to wear full-face supplied air respirators.

C. The waste ash "dustless" disposal system with its frequent problems was inadequate to control the dust hazard. Unless the current auger-slurry maker can be fine-tuned to properly mix water with ash during ash dumping, an improved system should be considered. Consider adding extra water nozzles in the auger assembly and at the exit port. Also, consider an automatic mixing and sensing device so the waste ash would be either mixed correctly, or not released.

RECOMMENDATION: The plant management should fix the "dustless" waste ash disposal system.

D. Physical exams should be considered for the plant workers based on their exposure. Exams should include pulmonary function tests and chest X-rays for those routinely working around coal and ash. Medical surveillance for all employees who are exposed to airborne concentrations of silica above the TLV should include:

1. A complete pre-employment history and medical exam with posteroanterior chest film and pulmonary function test including FVC and FEV.

2. Annual medical exams, chest films and pulmonary function test thereafter.

These requirements are included in OSHA directives on silica, OSHA Instruction CPL 2-27, CH-1, June 3, 1985. Additionally, personnel must be fit tested for respirator use.

RECOMMENDATION: The base Environmental Health Office should ensure the appropriate physical exams are determined and administered and that respirator fit testing and training be accomplished.

E. Coal fired heating plants need a strong on-going industrial hygiene program. Workers should be educated to the hazards and controls associated with coal and ash dust. More sampling should be done to determine TWA exposures to workers during infrequent procedures, such as summer maintenance, which we were unable to observe and sample during our survey. Be sure that when routine air samples are analyzed the silica contents must also be determined. This way the appropriate exposure limit can be used.

RECOMMENDATION: The plant management in conjunction with the base BEE should ensure a strong industrial hygiene program exists to include the required air monitoring, worker education and hazard control.

REFERENCES

1. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values and Biological Exposure Indices for 1987-1988, ISBN 0-936712-69-4, 1986

2. Project No. HAF-610, USAFOEHL Technical Report 78-58, Brooks AFB TX 78235, October 1978

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